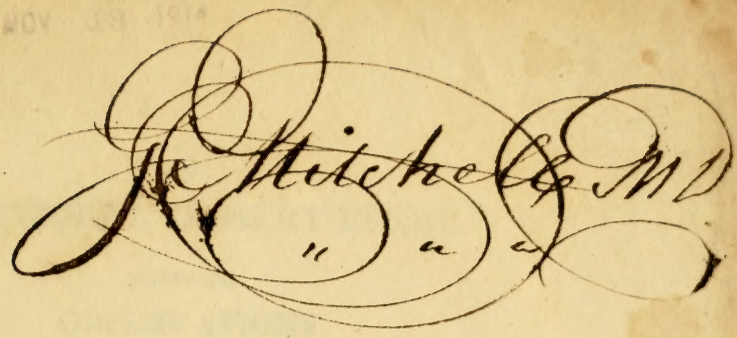
Gren. Lumbricus terrestris.
[1806]



INAUGURAL DISSERTATION

ON THE

LUMBRICUS TERRESTRIS.

AN

INAUGURAL DISSERTATION,

ENTITLED,

OBSERVATIONS

ON THE

STRUCTURE AND HABITS

OF THE

LUMBRICUS TERRESTRIS;

AND

A CHEMICO-PHYSIOLOGICAL ENQUIRY

ON ITS RESPIRATION.

SUBMITTED TO THE EXAMINATION

OF THE REV. JOHN ANDREWS, VICE-PROVOST, THE

TRUSTEES AND MEDICAL FACULTY OF THE

UNIVERSITY OF PENNSYLVANIA,

FOR THE DEGREE OF

DOCTOR OF MEDICINE,

ON THE

TWENTY-FIRST DAY OF APRIL, 1806.

BY ENOCH A. GREEN, A. M.

OF TRENTON, NEW-JERSEY.

PHILADELPHIA:

PRINTED FOR THE AUTHOR.

TO

DOCTOR NICHOLAS BELLVILLE,

OF

NEW-JERSEY.

MOST RESPECTED SIR,

PERMIT me thus publicly to acknowledge my obligation to you, for the useful instructions which I have obtained from you; for the friendship and polite attention which I have ever received from yourself and amiable family during my apprenticeship; At the same time to express the high opinion which I always have had, and still entertain of your talents, since the little progress which I have made in the science has made me the more competent to judge.

I entreat you therefore, to consider this essay as a tribute of gratitude; and to receive the warmest wishes for your health, happiness, and long continued success in your profession.

Your greatly indebted pupil and friend,

ENOCH A. GREEN.

INTRODUCTION.

THE respiration of animals has long been a difficult problem in physiology, and must have still remained so had chemistry continued in an uncultivated state. Within these last few years this science has been much improved, and has been applied to the respiration of the more perfect animals with great satisfaction.

Spallanzani has applied it to a number of beings holding a low station in the great genus of animals---such as several species of the snail: My object is to descend a link or two lower, and ascertain whether it is applicable to the common earth worm.

To avoid the danger of being misled by inaccurate observation, the experiments were repeated several

times with great care and attention---and frequently in the presence of some judicious person. As the testimony of the senses is not always sufficient, and the most careful observer is liable to err, I neither expect, nor even wish, the conclusions should be adopted until the experiments shall have been repeated by others; and if it should be found that I have erred in any part of them, I shall ever be ready to retract the assertion---for the interest of truth and the welfare of science are infinitely of more value than the reputation of an individual.

LUMBRICUS TERRESTRIS. LINN.

COMMON EARTH WORM.

SECTION I.

THIS animal is from three and a half inches to four and a half in length ; it possesses the power of increasing and diminishing itself in a remarkable degree ;* its figure is nearly cylindrical from about three fourths of an inch from each extremity ; its head is conical, and its tail flat, having its flattened surface parallel to the horizon. This particular figure of the tail is not always to be observed when it is in an active state, but is uniformly to be seen when in a state of torpor. Its body is composed of annular sections, the

* When speaking of the worm, I always consider it in a mean state, between the extremes of elongation and contraction.

tenth or twelfth of an inch in length, united to each other by a substance possessing considerable elasticity, on which depends its power of elongation and contraction. Its body is armed with four rows of small, stiff, sharp-pointed bristles, each annular section being furnished with four; they impart a rough sensation to the fingers in passing them from the tail to the head. These bristles assist to accelerate their motion thro' the earth. About three-fourths of an inch from its mouth are three whitish bodies extending across the belly; one fourth of an inch from these is another, having a similar structure and situation. These some naturalists say, are its genital organs. Three-fourths of an inch from the last mentioned body is a brownish coloured wreath, encircling the whole body. This wreath is perforated with a number of holes, as well as the body generally, all of which discharge a glutinous fluid, very analogous to that mucus which is secreted from the Schneiderian membrane; this discharge is of great importance in its economy---it lubricates the earth through which it moves and thereby makes its passage easy.

This wreath must perform an office of more importance than merely the secretion and excretion of mucus. The inflammatory appearance which it uniformly exhibits when the animal has been suffocated by being confined in impure air, induced me first to believe it was its respiratory organ. I endeavoured to determine it

by the following experiments: I obtained three of these animals and wrapped about the wreath of each, a piece of fine linen, previously dipped in sweet oil, and secured them in such a manner that it was impossible for the worms to get them off; expecting by these means to obstruct the pores, and kill the animals; but was disappointed in my expectation---They were kept in this situation in the earth two days without injury.

I am induced to believe, from the following facts, that this wreath must be their genital organs. In examining the younger tribe, I find they are not furnished with this structure, at least it is not visible, and the larger the animal, the greater proportion does it bear to the whole body. By a minute examination of this structure, of a full grown animal, in a strong light may be observed a number of cicatrices, occasioned probably by the passage of the ova.

I have been able to discover by the naked eye, that it is furnished internally, with blood vessels, an æsophagus, stomach, and intestines.

The white bodies that are situated near the head, which have been supposed by some to be the genital organs, appear to answer in some measure the function of a heart. All the large blood vessels pass through them, by making an incision here, a considerable hemorrhagy ensues, much greater than follows the section of the blood vessels in any other part of the body; consequently it may be looked upon as the source of

circulation. This animal is furnished with three blood vessels, of considerable size extending from the head to the tail. The largest runs along the back, and the other two along the belly. The one that passes along the back sends off a great number of ramifications on each side, opposite to each other, nearly at right angles ; each annular section has from it two branches, one running to the right and the other to the left, appearing to terminate in the largest that runs along the belly. Probably the vessel that is situated on the back is the artery which brings the blood from near the head ; and the largest one on the belly is the corresponding vein, which carries the blood back near the head, to the commencement of the artery. By a minute attention to the blood vessels, when the animal is in motion, I think the blood may be seen to move. This motion of the blood is not uniform as in the more perfect animals ; but flows only at intervals during the motion of the worm. May we not infer the circulation from the inspection of the distribution of the blood vessels ? We know that these vessels are given them for important purposes, and to reason from analogy, we can ascribe no other office to them than the circulation of that fluid which they evidently contain. The small vessel that runs along the belly lies more superficially, and is confined to the skin.

There is a curious fact relative to their blood vessels : They form a strait canal when in a state of

elongation; but when in a state of contraction, they are thrown into folds, in such a manner, that portions of the same vessel are parallel to each other. This necessarily arises from the particular manner by which they are attached to the adjacent parts by membrane. The same particularity of the blood vessels must be common to the snail, the leach, and to all animals that have the power of increasing and diminishing themselves in length.

The æsophagus extends in a direct line, to the stomach, which is about three-fourths of an inch. The stomach is near the size of a small pea of an irregular, oval form. Its external surface appears muscular, and its internal membranous. It generally contains earth, which is its common and natural food. The intestines commence at the stomach, and continue to the extremity of the tail; they lie in a convoluted form, when the animal is in a state of contraction; but are united by membrane in such a peculiar manner to the adjacent parts, as to form a straight canal, from the commencement of the æsophagus, to the extremity of the tail, when in a state of elongation.

Spallanzani,* in speaking of the barbel, says "the "conformation of the barbel does not correspond "with the carp, and various other fishes. The æso- "phagus, stomach, and intestines, constitute a single

* Dissertation III. Sec. CXXXII.

" gut, nearly as in the earth worms, and a variety of " other insects." If he meant in a state of elongation he is perfectly correct; if in a state of contraction, he is incorrect.

Earth worms are hermaphrodites, and have their parts of generation situated about an inch and a half from their mouth. They are oviparous animals. Their copulation is performed on the surface of the ground at different seasons of the year, where they mutually impregnate each other. I recollect perfectly, of observing them in that state, on christmas day, of the year 1801, which was remarkably mild.

These animals, which man tramples on with disdain, and looks down upon with scorn, are endued with life, motion, sensation, and every other animal faculty. They are found near the surface of the earth in moist, temperate seasons. They penetrate the earth with ease by their heads, which they are capable of making very pointed; and move with great facility in consequence of the mucilaginous substance, which is continually discharged from the surface of their bodies, when in motion. They come to the surface of the earth when it is sufficiently soft, particularly in the morning about the rising of the sun. After ten o'clock we seldom see them on the surface, unless driven out by something moving the surface, which reminds them of their formidable enemy, the mole. In the after part of the day they retire to their subterraneous habitation.

When a dry season commences they go in pursuit of moisture, are then to be found under stones---on the north side of fences---and in low situations. It is probable that many of them perish during a long drought, especially those that cannot find retreats sufficiently humid. This opinion derives support from the following fact. After the weather has continued dry for many weeks, then succeeded by heavy falls of rain, they are not to be found in half the numbers that they were before the commencement of the drought:* had they continued to descend so as to keep in the humid earth, we should have them in numbers equal to what we had before the beginning of the dry season---as it is well ascertained, that they always keep near the surface when there is humidity.

I wished to determine by an experiment, whether dry earth would prove destructive to them. I accordingly dried some earth, and put a number of worms into it; in the space of twelve hours, every symptom of vitality disappeared. They were then put into moist earth, and permitted to remain in it several hours, without any symptoms of being revived. Hence we may infer, these animals cannot live with-

* I have been informed by persons that are in the habit of digging the earth to a considerable depth, at all seasons of the year, that they never observe them any considerable distance below the surface; probably if they were to descend, the impurity of the air would prove fatal to them.

out humidity; and, that these humble beings are unknown in the desarts of Arabia, and the scorched sands of Africa.

Mr. Barbut observes, they differ extremely in colour and external appearance, in the different periods of their growth, which has occasioned people, little acquainted with the variations of these animals, to make four or five different species of them. The fertility, texture, and colour of the soil, have considerable influence on their natural appearance. In a rich soil they are more numerous and larger, than in one that is poor. There are but few to be found, and of an inferior size, in an argillaceous soil of a firm consistence---owing to its barrenness and the difficulty which they necessarily find in performing their little peregrinations. Those that inhabit a black soil are of a dark complexion; a yellow one, of nearly the same hue---so that their colour partakes in a great measure of the colour of their habitation.

It is supposed, by naturalists, that they keep always below the frost during the winter. I have examined the earth frequently the last winter, and have uniformly found them two or three inches below the frost, in a torpid state. The ground was not frozen more than six inches deep when I made the examination.

I wished then to ascertain, whether exposing them to the freezing point, would prove fatal to them; I

accordingly rolled a number of them in a ball of snow, and let them remain in that situation for twelve hours, after which I examined and found them in a state of torpor. They were exposed for a few minutes to the gentle stimulus of warm air---soon recovered, and became very active.

I wished then to know what effect freezing would have upon them. As the last winter was remarkably mild, I was obliged to have recourse to a frigorifick mixture.*---I put two worms into a glass tube, hermetically sealed at one extremity ; it was introduced into the mixture, where it remained ten minutes---removed it, and examined the animals, and found them dead, without any appearance of disorganization.

If we suppose the weather should set in cold, so as to freeze the ground four inches deep, and the worms lie two inches below the frost, in a torpid state ; should then the weather increase so much in severity as to freeze the ground ten inches, the animals must then be necessarily frozen, consequently there would be a possibility of their entire destruction. May they not be reanimated by the heat which is given out during the process of freezing, and thereby be enabled to descend into the earth and keep below the frost ?† We

* Composed of equal parts of nitre and salt, mixed with snow.

† In the beginning of March, when the ground was frozen from four to six inches, early in the morning I dug into the earth, and

know from observation, that a temperature one or two degrees above the freezing point, makes them inanimate; hence it is probable that the heat given out, during the time that the earth is freezing above them, will be amply sufficient to reanimate and enable them to descend.

SECTION II.

TO obtain the object proposed, it may not be improper, to endeavour to ascertain whether these animals are furnished with respiratory organs. The following are the repeated experiments that I have made on this subject.

found the animals about two inches below the frost, in a state of torpor. The thermometer applied to the surface of the earth stood at 31 degrees. By introducing it into the ground, where the animals lie in a torpid state, it rose to 33 degrees. By a minute attention to the animals, so as to see when they exhibited the first signs of life, at which time I immediately introduced the thermometer, and it rose to 34 and a half degrees; as soon as they began to move, they also began to descend into the earth.

EXPERIMENT I.

I passed a ligature around the head and tail of a worm---weighed it, and put it into water; after remaining in it twenty-four hours, it had increased in weight twenty grains. The animal received no injury from the experiment.

EXPERIMENT II.

I filled a phial with water two-thirds full, which had been previously boiled; introduced into it two worms, and corked it perfectly tight, so as to cut off the communication of the external air. The animals lived thirty-six hours.

EXPERIMENT III.

At the same time, I filled a phial with water, two-thirds full, which had not been boiled, and introduced into it two worms; the phial was left open so that there might be a free access of air. They were permitted to remain in this situation one week; at the expiration of which time they were active, and appeared to enjoy good health.

EXPERIMENT IV.

I introduced a number of worms into sweet oil; in which they died in a few hours. It may be said, that it was the deleterious effects of the oil that proved de-

structive to them : but their actions, immediately after being immersed, exhibited no signs of pain or uneasiness.

From these experiments we may draw the following conclusions :

1. That these animals have the property of absorbing water through the the medium of the surface. As they possess the property in an eminent degree, is it not equally probable that the air, which is a more subtle fluid, may be absorbed through the same medium ?

2. That they live but a short time in water that has been previously boiled ; and that they possess not the power of decomposing the water.

3. That they can live a long time in water that has not been boiled, and has a free communication with the air.

4. That they soon die in oil, in consequence of their pores being obstructed ; that these animals have organs which perform the office of lungs ; and, that pure air is necessary for their vitality.

SECTION III.

TO ascertain the effects produced on atmospheric and oxygen airs, by these animals, I performed all the experiments over mercury, to prevent the absorption of the carbonic acid gas, if any there should be, produced by the supposed respiration of the animals.

EXPERIMENT I.

I filled a glass vessel with mercury, and inverted it on the shelf of the pneumatic apparatus, and transmitted into it two measures of atmospheric air, previously washed in lime water; into which was introduced four worms, washed and wiped perfectly dry. There was placed under them a small circular piece of wood, by which they were separated from the mercury during the experiment, which might have proved injurious to them. The piece of wood employed was less in diameter than the vessel. They lived in this situation fifty-four hours; and were then removed by a piece of wire bent at one extremity. The next thing to be done was to ascertain what change had been produced on the air in which the worms had been confined. After having filled an eudiometer with lime water, and introduced into it a measure of the air, corresponding to the graduated portion of the instrument; by agitating it, the water rose 12 degrees: consequently

the worms had produced 12 degrees of carbonic acid gas. A stick of phosphorus was introduced into the eudiometer, and left remaining in that situation for two days—at the expiration of which, there was an absorption of 10 degrees; consequently the animals had not consumed all the oxygen.*

EXPERIMENT II.

I obtained oxygen gas from the black oxyde of manganese; in order to have it perfectly pure it was well washed with lime water; proceeding in the same manner as in the preceding experiment. I transmitted two measures of this gas into the vessel, into which were put four worms of nearly the same size as possible of those employed in the experiment above. They lived in this situation four days and six hours; nearly double the time that the same number of animals lived in the same quantity of atmospheric air under similar circumstances. When we came to examine the air, we found that one half had been consumed; the remainder was transferred into the eudiometer; after being filled with lime water, by agitating the air, the water rose 25 degrees---consequently the worms had produced twenty-five per cent. of carbonic acid gas.

* The air of this, and the following experiment was examined by the professor of chemistry, whose accuracy is notorious.

Being anxious to know if it were possible to obtain a complete consumption of the oxygen gas by means of these worms, I endeavoured to bring it to the test, by confining a greater or less number of them in common air. They were confined at the superior part of the vessel, to keep them out of the fixed air, which they produce in ratio to the oxygen destroyed. This air, being specifically heavier than common air, will necessarily descend to the bottom of the vessel. I observed those animals died sooner at the bottom than at the top of the vessel---owing to the fixed air produced during their confinement, which will hereafter be shown to be very noxious to them. By these means I was able to cause a great consumption of the oxygen ---but not completely.

The weather was changeable during the time I was making these experiments. I found that it may be established as a law, that the death of these animals, as to time, is in proportion to the temperature of the air in which they are confined; so that they die so much the later as the temperature is diminished. In the first case the oxygen disappears sooner than in the second. Probably this law is applicable to all animals that pass the winter in a state of torpor. The reason is evident: These animals belong to the cold blooded class; we know that they are weakened by too low a temperature, that they become benumbed and inanimate. We find also that the gentle stimulus of a mild

atmosphere reanimates their powers and gives them new energies. In the first case they are more feeble, and their organs less susceptible of performing their functions, than in the second ; and consequently these animals will live longer in proportion as the consumption of the oxygen is slower : as it has been demonstrated that oxygen is necessary for their vitality in the preceding experiments.

Having proved in a satisfactory manner, that oxygen is requisite for the existence of these worms, I was induced next to ascertain what effect the gases would have on them, that is improper for the respiration of the more perfect animals.

EXPERIMENT III.

I obtained nitrogen ; by making a quantity of sulphur and iron filings into a paste with water, and placed the mixture in a plate over water, on a stand raised above the fluid, then inverted over it a bell-glass, and allowed it to stand three or four days, by which time an absorption of near a fifth had taken place. To be satisfied that it was perfectly pure, I made a saturated solution of the sulphuret of pot-ash, and washed the nitrogen with it for some time. I filled the vessel as before with mercury, and placed it on the shelf of the apparatus, transmitted the nitrogen into the vessel, and caused a number of worms to pass into it : they first moved about with great activity, as if they suffer-

ed pain; in a short time became less active; but symptoms of life were evident from four to six hours in the different experiments which were performed.

They live in nitrogen longer than we might suppose, agreeably to its effects on other animals. When we reflect on their living under ground, and the many causes that may prevent them from coming to the surface, we must be sensibly impressed with the wisdom of nature, in giving them constitutions susceptible of enduring a considerable space of time the prescence of impure air.

The worms that have been kept in this gas, remain longer in a state of asphixia than when confined in any other; and may be recovered, by a proper mode of treatment, after fifteen or twenty hours confinement.

EXPERIMENT IV.

I procured carbonic acid gas from pulverized marble, by the addition of the sulphuric acid, diluted with water. I placed the extremity of the syphon so as to receive the gas in the vessel in which the experiment was to be performed. I caused a number of worms to pass into the vessel containing the fixed air: immediately after they came in contact with the air they exhibited signs of pain, moved about rapidly, were convulsed, and in ten minutes had the symptoms of being dead. They were left in this situation precisely one half hour; I then examined them, and found their

bodies flacced without any signs of life. I was anxious to ascertain whether it was possible to revive them. To effect this I supposed the most likely way to succeed would be to put them into moist earth, and expose them to the sun. In the space of half an hour they exhibited feint signs of life, moved their tails feebly, and shortly expired.

The same experiments were repeated three times, under similar circumstances, with the same result. When they were permitted to remain in the fixed air two hours, it was impossible to revive them by the same mode of treatment.*

EXPERIMENT V.

I obtained the muriatic acid gas from common salt, by the addition of the sulphuric acid. Having transmitted it to the vessel in which the experiment was to be performed, I took two worms, washed them in rain water, and wiped them perfectly dry, and caused them to pass into the vessel containing the gas. It was instant death to them, without the least signs of pain. The mercury began to rise in the vessel as soon as they were introduced. I supposed it was owing to the gas disorganizing their bodies, and causing the fluid which they contain in a state of health to be discharged, which absorbed the gas and

* The properties of this air as an anthelmintic, by injection, was mentioned by the professor of Materia Medica in his lectures.

formed the marine acid. The mercury would be necessarily forced up into the vessel by the pressure of the external air. On examining the animals, I found the bodies were corrodded. The fluid formed on the surface of the mercury was the muriatic acid.

EXPERIMENT VI.

I obtained hydrogen gas from iron filings, by the addition of the diluted sulphuric acid. Having introduced it into the vessels, four worms were caused to pass into it. They moved about a few minutes with symptoms of pain, in the space of twenty minutes every sign of life disappeared. They were then removed, and the same means employed to revive them as in a former experiment; in ten minutes symptoms of life returned, and in two hours they were so much revived as to move with activity; but never recovered their health completely.

I repeated the experiment with the same result. Those that were permitted to remain in the gas four hours could not be recovered by the same mode of treatment.

The inflammatory appearance which the parts near the heads and the genital organs exhibited, after being removed from the vessels in which they had been confined, and exposed to the open air, induced me to suppose that the change produced on the blood of the

animal must be owing to the combination of the oxygen of the atmosphere with it.

EXPERIMENT VII.

In order to ascertain whether this change wrought on the blood by removing the animal from its place of confinement to the open air—I first took two worms that had been killed by being confined in atmospheric air, and introduced them into a vessel containing nitrogen, where they remained four hours. They were then removed and examined: but no change of the colour of the blood was discernible. The same animals were introduced into a vessel containing oxygen, and permitted to remain the same length of time —were then removed and examined, and there was an evident change of the blood from a dark to a florid colour—observed by two gentlemen who were also present. I also took some animals that had been confined and perished in nitrogen, whose blood was of a dark colour, and put them in a vessel containing oxygen; after remaining in it a few hours it assumed a florid appearance. The same animals were returned into the nitrogen, and the blood lost its bright colour in a considerable degree.

If the animals are removed from the place of confinement immediately after death no marks of inflammation are present; but in the space of an hour, generally, there was a perceptible enlargement of the parts

near the head and genital organs, which continued to encrease from three to four hours under certain circumstances. The reason is evident: These animals belong to the cold-blooded class, consequently the circulation of the blood is very slow; and the circulation of the blood of animals, belonging to this class will continue several hours after death—as the blood is not so soon effected by the change produced on the body by death, as on those animals belonging to the warm-blooded class.

We also know that the more perfect animals, when killed by suffocation, that the blood always has a tendency to stagnate about the parts essential to life; the same thing holds good in these humble creatures.

The following conclusions may be drawn from the preceding experiments.

1. That the lumbricus terrestris has organs that perform the office of respiration.

2. That these worms consume nearly all the oxygen of atmospheric air, and that it is necessary for their vitality.

3. That the carbonic acid gas which is formed, when confined in the atmospheric air, is equal to the quantity of oxygen consumed.

4. That they live nearly as long again in oxygen as in atmospheric air, and that the quantity of carbonic

acid gas produced is not equal to the oxygen consumed.

5. That the same number of animals confined in oxygen, the same space of time, under similar circumstances, consume more of it than when confined in atmospheric air.

6. That nitrogen is less noxious to them than any of the gases that are fatal to animal life.

7. That fixed air is most deleterious to them.

8. That muriatic acid gas disorganizes their structures.

9. That the flammable air is also very noxious to them.

10. That the temperature of the air accelerates the consumption of the oxygen, and also the death of the animals.

11. That the florid colour of the blood is owing to the combination of oxygen with it.

These phœnomena have the greatest analogy to respiration. If we confine a quadruped in common air the oxygen is destroyed. Worms perform precisely the same operation. From the similarity of effects we must ascribe a similarity of causes: And hence the theory of modern chemistry is applicable to these animals.

Before I take my leave of this subject entirely, I should do injustice to my own feelings were I not to return my sincere thanks to the medical professors, for the instructions I have received from their lectures, and the many opportunities of improvement I have experienced through them, while a student in this university.

FINIS.